

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis.1 and
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

VENNER, SHIPLEY & CO.
20 Little Britain
London EC1A 7DH
ROYAUME-UNIRECEIVED
JUL 12 2002
Technology Center 2600

Date of mailing (day/month/year)

29 April 2002 (29.04.02)

Applicant's or agent's file reference

16 36733

IMPORTANT NOTIFICATION

International application No.

PCT/GB00/03752

International filing date (day/month/year)

29 September 2000 (29.09.00)

1. The following indications appeared on record concerning:



the applicant



the inventor



the agent



the common representative

Name and Address

SENTEC LTD.
Terrington House
13-15 Hills Road
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United Kingdom

State of Nationality

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State of Residence

GB

Telephone No.

Facsimile No.

Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:



the person



the name



the address



the nationality



the residence

Name and Address

BTG INTERNATIONAL LTD
10 Fleet Place
Limeburner Landed
London EC4M 7SB
United Kingdom

State of Nationality

GB

State of Residence

GB

Telephone No.

Facsimile No.

Teleprinter No.

3. Further observations, if necessary:

4. A copy of this notification has been sent to:



the receiving Office



the designated Offices concerned



the International Searching Authority



the elected Offices concerned



the International Preliminary Examining Authority



other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Authorized officer

Kiwa MPAY

Facsimile No.: (41-22) 740.14.35

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE
in its capacity as elected Office

Date of mailing (day/month/year) 28 May 2001 (28.05.01)	
International application No. PCT/GB00/03752	Applicant's or agent's file reference 16 36733
International filing date (day/month/year) 29 September 2000 (29.09.00)	Priority date (day/month/year) 01 October 1999 (01.10.99)
Applicant DAMES, Andrew, Nicholas et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:

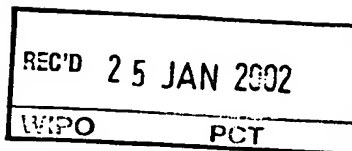
27 April 2001 (27.04.01)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was
☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer Olivia TEFY Telephone No.: (41-22) 338.83.38
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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 16 36733	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/GB00/03752	International filing date (day/month/year) 29/09/2000	Priority date (day/month/year) 01/10/1999
International Patent Classification (IPC) or national classification and IPC G06K19/06		
Applicant SENTEC Ltd		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.



2. This REPORT consists of a total of 5 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☒ Certain observations on the international application

Date of submission of the demand 27/04/2001	Date of completion of this report 24.01.2002
Name and mailing address of the international preliminary examining authority:  European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized officer Chiarizia, S Telephone No. +31 70 340 3771 

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/GB00/03752

I. Basis of the report

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

Description, pages:

1-15 as originally filed

Claims, No.:

1-16 as originally filed

Drawings, sheets:

1/3-3/3 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/GB00/03752

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims
	No:	Claims 1,2,4,5,16
Inventive step (IS)	Yes:	Claims
	No:	Claims 3,6-15
Industrial applicability (IA)	Yes:	Claims 1-16
	No:	Claims

- 2. Citations and explanations**
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB00/03752

Reference is made to the following document:

D1: WO-A-9928852

Novelty: Art. 32(2) PCT

Document D1 discloses (see page a magnetic tag for storing data 14, line 7 - page 16, line 10 and fig 4) a magnetic data comprising magnetic elements the magnetic properties of which are used for coding data.

The subject-matter of claim 1 and 16 is therefore not new.

D1 also discloses the features of claims 2,4,5. Their subject-matter is therefore not new.

Inventive step : Art. 33(3) PCT

Dependent claims 3,6-15 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of inventive step.

Rule 9.1 (iv) PCT :

All "incorporated by reference " on pages 1 and 8 should have been deleted.

Rule 6.3 PCT :

Independent claims are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D1) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

Independent claims should have been therefore redrafted accordingly. If, however, the applicant were of the opinion that the two-part form would be inappropriate, then reasons therefor should have been provided in the letter of reply. In addition, the applicant should have ensured that it was clear from the description which features of the subject-matter of the independent claims were already known in combination from the document D1 (see the PCT Guidelines, III-2.3a).

Rule 6.2(b) PCT :

The features of the claims should have been provided with reference signs placed in parentheses.

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB00/03752

Rule 5.1(a) PCT :

The relevant background art disclosed in D1 should have been mentioned in the description and the document identified therein.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 16 36733	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 00/ 03752	International filing date (day/month/year) 29/09/2000	(Earliest) Priority Date (day/month/year) 01/10/1999
Applicant SENTEC Ltd		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

☐ as suggested by the applicant.

☒ because the applicant failed to suggest a figure.

☐ because this figure better characterizes the invention.

1
☐ None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/ 00/03752

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06K19/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, IBM-TDB, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 195 35 019 A (CARDTEC ENTWICKLUNGS UND VERTR) 27 March 1997 (1997-03-27) column 4, line 29 - line 62; figure 1 ---	1,2,4-6, 11,12, 14,16
X	US 4 940 966 A (PETTIGREW ROBERT M ET AL) 10 July 1990 (1990-07-10) column 3, line 51 - line 68; figures 3,4 claim 2 ---	1,2,4-6, 11,12, 14,16
X	WO 99 28852 A (TECHNICAL GRAPHICS SECURITY PR) 10 June 1999 (1999-06-10) page 14, line 7 -page 16, line 10; figure 4B -----	1,2,4-6, 11,12, 14,16



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- * & * document member of the same patent family

Date of the actual completion of the international search

6 December 2000

Date of mailing of the international search report

13/12/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Chiarizia, S

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/00/03752

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19535019 A	27-03-1997	NONE	
US 4940966 A	10-07-1990	AT 88294 T AU 613045 B AU 1746388 A BR 8802873 A CA 1291244 A DE 3855645 D DE 3880202 A DE 3880202 T DK 58089 A DK 171570 B EP 0295028 A EP 0295085 A ES 2040343 T WO 8809979 A JP 1064207 A JP 2643312 B JP 1503577 T NO 882504 A,B, US 4960651 A	15-04-1993 25-07-1991 08-12-1988 03-01-1989 22-10-1991 12-12-1996 19-05-1993 05-08-1993 08-02-1989 13-01-1997 14-12-1988 14-12-1988 16-10-1993 15-12-1988 10-03-1989 20-08-1997 30-11-1989 09-12-1988 02-10-1990
WO 9928852 A	10-06-1999	AU 1800899 A BR 9815359 A EP 1034504 A NO 20002850 A	16-06-1999 21-11-2000 13-09-2000 24-07-2000

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



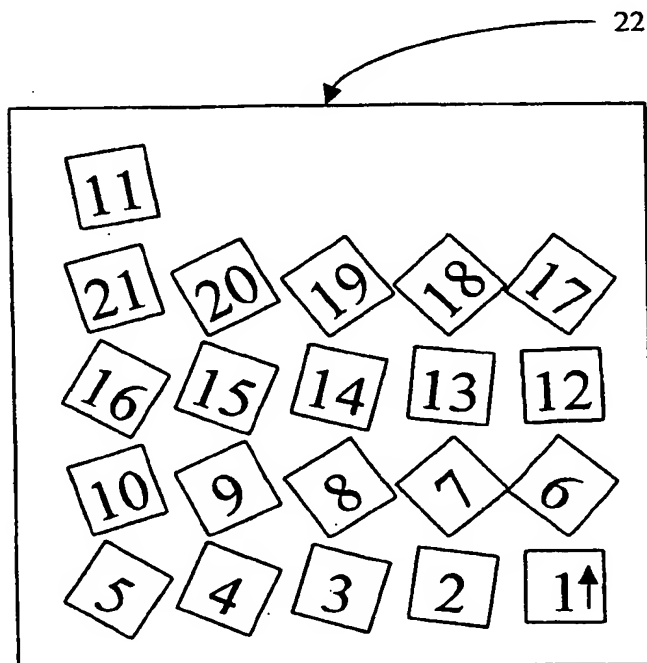
(43) International Publication Date
12 April 2001 (12.04.2001)

PCT

(10) International Publication Number
WO 01/26049 A1

- (51) International Patent Classification⁷: G06K 19/06 (74) Agent: VENNER, SHIPLEY & CO.; 20 Little Britain, London EC1A 7DH (GE).
- (21) International Application Number: PCT/GB00/03752
- (22) International Filing Date:
29 September 2000 (29.09.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
9923199.5 1 October 1999 (01.10.1999) GB
- (71) Applicant (for all designated States except US): SENTEC LTD. [GB/GB]; Terrington House, 13-15 Hills Road, Cambridge CB2 1GE (GB).
- (81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- (72) Inventors; and
(75) Inventors/Applicants (for US only): DAMES, Andrew, Nicholas [GB/GB]; 74 De Freville Avenue, Cambridge CB4 1HU (GB). ENGLAND, James, Mark, Carson [GB/GB]; 44a Butt Lane, Milton, Cambridge CB4 6DG (GB).
- Published:
— With international search report.
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MAGNETIC TAGS



(57) Abstract: A magnetic data tag comprises a plurality of magnetic elements in which data is stored by reference to a combination of characteristics selected from a large number of possible characteristics. One characteristic such as orientation or location is used to distinguish elements from one another and another characteristic such as coercivity or amplitude response is used to store multiple bits of data per element. Further characteristics are used to store additional data.

WO 01/26049 A1

Magnetic Tags

Field of the Invention

This invention relates to the field of magnetic tags for storing data, particularly but not exclusively to tags in which data is stored by reference to a combination of magnetic element characteristics.

Background

PCT publication number WO99/35610 describes tags and reader systems primarily intended for tags fabricated from magnetic material of low coercivity, with elements at different orientations, in which data is recorded primarily by means of the orientation of the elements with respect to each other. The described system assumes that the coercivities of the tag elements are all the same, and are very small compared to the interrogation field.

Co-pending application no. PCT/GB00/03092, which is incorporated herein by reference in its entirety, describes a reading system for decoding magnetic tags including tags according to the present invention.

Summary of the Invention

According to the invention, there is provided a magnetic tag for storing data, comprising at least one magnetic element configured such that the data is stored by reference to a combination of two or more characteristics associated with the or each element.

Advantageously, a first one of the characteristics can be used to identify or distinguish the elements from one another and a second one of the characteristics can be used to store data. One or more further characteristics can be used to store additional data.

There is no limit on the type of characteristic which can be used and it can be any measurable magnetic property or parameter such as location of an element or presence or absence of an element. The characteristics can include one or more

selected from element coercivity, element bias, element orientation, amplitude
response of an element, response bandwidth, dependence of element switching field
in response to the rate of change of an applied field, element switching speed,
element location, maximum cross-field bias, permeability, Barkhausen response and
5 resonant frequency.

The magnetic tag can comprise a plurality of magnetic elements, each of the
magnetic elements being disposed in a different orientation by which it is
distinguishable from the other elements and each having a magnetic bias member
10 capable of assuming a plurality of states, wherein data is stored by the state assumed
by the magnetic bias member. Further data can be stored by the orientation of each
of the elements being selected from a set of possible orientations. Additional data
can also be stored by arranging for one or more of the elements to exhibit a
different coercivity and/or a different amplitude response from that of the other
15 elements.

The magnetic tag can alternatively comprise a plurality of intersecting magnetic
elements, each of the magnetic elements being disposed in a different orientation by
which it is distinguishable from the other elements and each having a coercivity
20 selected from a set of possible coercivities, whereby to store data. The relative
orientations of the elements can be used to identify the elements and to store data,
and the coercivities of the elements can be used to store further data.

Yet further, the magnetic tag can comprise a plurality of magnetic elements, each of
25 the magnetic elements being disposed in a different orientation by which it is
distinguishable from the other elements and each being located at one of a plurality
of possible locations whereby to store data.

The magnetic tag can also comprise a plurality of magnetic elements, each of the
30 magnetic elements being located at one of a plurality of possible locations and each
having a coercivity which is selected from a set of possible coercivities, whereby to
store data.

Brief Description of the Drawings

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

- 5 Figure 1 illustrates a 40-bit programmable thin-film data tag;
- Figure 2 illustrates a portion of a thin-film data tag in which data storage density is increased by varying the width of each element;
- Figure 3 illustrates a portion of a thin-film data tag in which data storage density is increased by varying the relative orientation of the elements;
- 10 Figure 4 shows a 7-element coercivity-angle-encoded data tag;
- Figure 5 shows a 7-element location-angle-encoded data tag; and
- Figure 6 shows a 7-element coercivity-location-encoded data tag.

Detailed Description

Passive magnetic data tags in accordance with the invention comprise one or more
15 magnetically active dipole elements. The primary constraints on data tag construction are:

1. Amount of data (number of bits)
2. Physical size
3. Reading method
- 20 4. Programmability

Within these constraints, there are many alternative arrangements that can achieve the same result. Some embodiments are particularly favourable, in terms of the tag construction and the complexity of the reading/decoding process, for example,
25 those in which:

1. More than one property varies between elements, for example selected from orientation, bias, response amplitude (i.e. saturated dipole moment), coercivity and location (or presence/absence) of an element.
- 30 2. One parameter is used to distinguish the element, and one or more other parameters are used to store the data.
3. The number of bits of data per magnetic element is greatest.

The embodiments described below do not represent the ultimate data capacity of the tag. The data capacity can be maximised by using more elements, by varying more properties, and by increasing the resolution of the reading system to
5 distinguish between more states, for example, closer orientations or similar amplitude. In general terms, the more complex the tag becomes, the less robust the reading system becomes. In the general case where there are n different elements, and m different states for each element, in total there are m^n different possible states. There are $2n$ ambiguities related to which way up the tag is, and which
10 element is which, leading to $m^n / 2n$ possible states. The achievable data density is about 100 bits of data.

A first example of the invention is described with reference to Figure 1. A plurality of magnetic elements 1-21 are arranged on a substrate 22, each at a different
15 orientation, and each with a different bias field. The orientation is used to identify and distinguish the elements, and the bias state of each element is used to store data. Each element occupies a different position on the tag. In the simplest implementation, no information is stored in the position, coercivity or amplitude or by reference to any other properties.

20 Each element consists of a $9 \times 9 \text{ mm}^2$ square of soft magnetic material, for example, Atalante™ thin film material (manufactured by IST of Zulte, Belgium, part number SPR97017A). This material has an "easy" axis of magnetisation, which provides a nominal orientation or direction for the element, or, in other words, the material
25 exhibits a directional response to an applied magnetic field. Directly on top of each element is placed a layer of a hard magnetic material, for example, ferric oxide recording tape, with a coercivity of 24 kA/m, and a film thickness of $10 \mu\text{m}$. This magnetic material is anisotropic, and the axis of magnetisation is aligned with that of the soft material.

30 The elements 1-21 are arranged on a square grid with a pitch of 10mm. Each element 1-21 is rotated to a different angle, as shown in the following table.

Element	Angle
1	0°
2	8°
3	16°
4	24°
5	32°
6	40°
7	48°
8	56°
9	64°
10	72°
11	80°
12	88°
13	96°
14	104°
15	112°
16	120°
17	128°
18	136°
19	144°
20	152°
21	164°

Table 1

The magnetic recording film can be in one of four states: unmagnetised; magnetised
5 parallel to the nominal direction of the element; magnetised at 180° to the nominal
direction of the element; or magnetised with an AC waveform to produce a
magnetisation pattern at a pitch of, for example, 1.8mm. This final state has the
effect of turning the element "off", i.e. preventing it from generating any response
in the interrogation field. Each element therefore has four states, and can store 2
10 bits of data.

The angular gaps between the last two elements 20, 21, and between the last element 21 and the first element 1 are 12 and 16 degrees respectively. All the other elements are at 8 degrees with respect to their neighbours. In a reader system for the tag, the two larger gaps provide a reference mark, so that the elements can be correctly ordered.

The total number of bits that can be stored by the tag is $2 \times 21 = 42$ bits. The total amount of useful data that can be stored is slightly less: one bit of data is lost because there is an ambiguity whereby all the elements are magnetised the other way around. In addition, a number of states are not allowed. These are states in which all the elements are turned off (the extreme case), and more generally states in which the first and final two elements 1, 20, 21 are turned off, as this prevents correct identification of the elements. Thus, a conservative figure for the total amount of useful data that can be stored is 40 bits.

The tag is read, in the simplest case, using a rotating magnetic field of around 2.5 kA/m. At this interrogation field, magnetising the film moves the position of the transitions by about 1° .

The tag can be made more compact by placing the lower two rows (elements 1-10) on top of the upper two rows (elements 12-21). This is because the elements above each other are orthogonal.

There are a number of programming methods for the above described tag, starting from a fully demagnetised tag, for example:

1. A gapped "recording head", similar to those used for standard magnetic tape, is used to magnetise the tape;
2. A small permanent magnet is used to magnetise the recording film in either direction. AC magnetisation can be achieved using a magnet with alternate north-south magnetisation;

3. The tag is manufactured initially without recording film. Pre-magnetised film is then stuck onto each element as required; and
4. All elements are programmed in parallel, using a multipole ferrite magnet arrangement: each element is magnetised by a separate ferrite element, with
5 separate coil connections. This permits all four states of all 21 elements to be defined.

In the embodiment described above, the tag stores information by the magnetisation of the bias element above the soft magnetic material. No
10 information is stored in the soft element orientation, amplitude response or coercivity. To increase the data density, one or more of these parameters is varied for each element. Our co-pending application PCT/GB00/03092 describes how these parameters can be read independently, for each soft element.

15 Alternatively, the same data density can be achieved using fewer magnetic elements. This has many practical advantages. The materials costs of the tag are lower, the tag can be smaller, and the reader system is able to distinguish more tags in the same volume.

20 For example, using film elements, each element can be made narrower than 9mm (perpendicular to the easy axis). In the simplest case illustrated in Figure 2, two widths are allowed – 9mm and 5mm and first, eighth and ninth elements 1,8,9 are shown with the reduced width. This scheme codes approximately an extra 1 bit for each element. In practice, there are seven states rather than eight since it is not
25 possible to differentiate tags in the off state. If the reading system can discriminate more amplitudes, then more information can be stored as a function of amplitude. The amplitude response can be changed by altering the size of the dipole element. Alternatively, the magnetic bias layer can be used to alter the dipole's effective width and length, by recording AC patterns on part of the film. Mechanical damage
30 of the magnetic material can also be used to alter its effective geometry.

In the examples described above, most of the angular gaps between elements are identical. More data is coded by allowing these gaps to be unequal. For example,

the gaps in the examples above are all 8° . By allowing these to be (for example) 7° or 9° , as shown in Figure 3, an extra 1 bit may be encoded for each element. An upper limit of different states is for example around 4 states – e.g. 6.5° , 7.5° , 8.5° and 9.5° . The design retains the feature of at least one large gap, for example a gap
5 between the last and first elements, larger than any other gap, referred to herein as the “big gap” feature, so that the elements are always read in order. This also means that certain combinations of states (e.g. all with large angles) are not allowed, as the big gap would become too small. This is similar to the data encoding described in publication no. WO99/35610, which is incorporated herein by
10 reference in its entirety. For a simple reader system, the minimum gap between elements must not be so small that the signals from two elements overlap or cannot be distinguished unambiguously. In practice, this means that fewer elements can be used. For example, using the four states above, the tag would be reduced to 17 elements, coding 28 bits of pre-programmed data (by the orientation) and 32 bits of
15 programmable data (by the bias field).

All the elements in the examples described above have the same coercivity (near zero to about 10 A/m). By allowing each element to have a coercivity selected from a set (for example a set of two or a set of four), additional information can be
20 encoded by each element. About 2 bits of additional data can be stored in this way. In practice, the maximum number of elements used is reduced.

In all the described cases, the gain in data capacity is less than the maximum number of states added, because certain states are indistinguishable – for example,
25 those in which elements are turned off by the bias field, but have different amplitude, orientation or coercivity. In addition, most of these alterations lead to reduced number of elements in practice. It will be understood by the skilled person that the various arrangements described above can be combined to provide tags in which data is stored by any two or more properties, for example, a tag in which
30 elements differ in amplitude response, coercivity, orientation and bias.

In a further embodiment, a particularly favourable class of tags can be made from elements selected from a range of available coercivities, and arranged at different

angles to each other. Data is stored primarily by the coercivity of the wire, and by the angles between the wires.

In this embodiment, illustrated in Figure 4, there are 7 magnetic elements 23-29.

- 5 Each element is a glass-coated amorphous metal wire, 29mm long, with a metal core diameter of around 10 μm , and an overall diameter of around 25 μm , made, for example, by the Taylor-Ulitovsky method. See for example M. Vazquez, A.P. Zhukov : "Magnetic properties of glass-coated amorphous and nanocrystalline microwires" : J. Magn. Mat. 160(1996) 223-228, and J. Gonzalez, N. Murillo, V. Larin, J.M. Barandiaran, M. Vazquez, A. Hernando: "Magnetic bistability of glass-
- 10 covered Fe-rich amorphous microwire: influence of heating treatments and applied tensile stress": Sensors and Actuators A 59(1997) 97-100. This material is magnetically bistable, with nearly rectangular B-H characteristics and rapid switching characteristics. Alternatively, the elements can be constructed from other
- 15 forms of wire, ribbon or film, such as cold-drawn amorphous metal wire, for example type 5T, a Barkhausen wire manufactured by Unitaka, Japan. Suitable materials are available from a number of other manufacturers (e.g. Vacuumschmelze, Germany, Allied Signal, Four Winds Inc., USA). In general terms, suitable materials exhibit rapid switching transients in fields changing at
- 20 more than 100,000 A/m/s, the field level at which these switching transients occur ("coercivity") depends on the material type and a number of different coercivities of material are available.

- The elements are chosen from a set of 7 different coercivities in the range, for
- 25 example, 20-300 A/m. These coercivities are denoted A-G in the following description, with, for convenience, A as the lowest and G as the highest coercivity. The 7 elements are disposed on a substrate 30, at different angles to each other. In the preferred configuration, the elements do not bisect. This is to avoid effects where the tag elements are deformed by all crossing at the same point. The
- 30 preferred configuration also minimises element-element interactions, and keeps the thickness of the tag to a minimum.

The tag data is stored by a combination of angle and coercivity. For the 7-element embodiment described, the angular separations are used to identify the elements, and to store four decimal digits of data, which form the four least significant decimal digits of the data.

5

There are six standard allowable angles between any two elements, as follows:

<i>Value</i>	<i>Degrees</i>
0	10
1	15
2	20
3	25
4	30
5	35

One gap between elements is required to be bigger than any of the other gaps, referred to herein as the big gap. This can exceed 35 degrees, and is used to provide a datum. The six remaining gaps are split into two halves – three gaps clockwise from the big gap, and three gaps anticlockwise. Not all combinations of gaps are allowed (e.g. all gaps equal to 35 degrees), because the sum of all the gaps in the tag must equal 180 degrees. To maximise the coding scheme efficiency, all combinations of three consecutive gaps are sorted by the total angular space required. A lookup table is generated to convert between the three gaps and position in this sorted list. Combinations of three gaps involving two or more of the smallest gaps are, for example, omitted, as these can be more difficult to decode in a reader system.

20

Both of the three-gap sequences are converted into positions (numbers) in the sorted look-up table. The coding scheme directs that one of these two resulting numbers is required to be larger than the other (equal numbers are not allowed).

The tag is read starting from the big gap, and working through the smaller numbers initially.

25

The tag elements can be unambiguously identified simply by finding the largest gap, and working out which way round to read the tag - i.e. starting with the smaller of the three gap sequences.

5 Once the tag elements have been identified individually as described, further data can be stored and retrieved by measuring other specific properties of each element. In the preferred embodiment, this is simply the coercivity of the element. A 7-digit base-7 number can be constructed from the elements taken in a specific order, by assigning A=0, B=1, C=2 ... G=6. For example, the combination of wires
10 ABCDEFG would correspond to the base-7 number 0123456, i.e. 22875 decimal. To generate the complete tag code, this number is multiplied by 10,000 and added to the value from the angular arrangement. There are about 33 bits of data in this arrangement.

15 The data storage capacity of the coercivity/angle tag described above can be increased in a number of ways. One way to increase the data content is to use more elements. For example, using 9 elements instead of 7, 1,000,000 different angular arrangements can be generated, and $9^9 = 387420489$ states can be stored by coercivity, giving a total data content of about 48 bits.

20 A further way of increasing data content is to select the wires from a wider range of material types. If there are more types of magnetic material to choose between, then more data can be stored per wire. For example, 8 different states stores 3 bits/wire; 16 states stores 4 bits/wire. It quickly becomes impractical to increase
25 the number of coercivity states above about 20 states. However, many other properties vary between different types of material. For example, certain types of wire show a dependence in switching field on the rate of change of the applied field dH/dt , depending on the conditions of manufacture. This dependence can differ strongly, even for wires of very similar coercivity. Similarly, material switching
30 speeds and switching amplitudes can also vary independently from each other and the coercivity. Switching speeds generally depend on the material construction (for example, glass-coated wire, cold-drawn wire, thin-film and so on), whereas amplitude can also be altered by changing the physical properties of the element, for

example, its length, or for thin-film materials, its width. Each of these differences can be combined to enumerate many more different material types – for example:

	Coercivity:	3 bits	(8 coercivities)
5	dH/dt	1 bit	(e.g. little/large variation)
	Speed:	1 bit	(e.g. fast/slow switching)
	Amplitude:	1 bit	(e.g. high/low amplitude)

Even with relatively simple discrimination between two states (=1 bit), for each
10 additional property, the data stored by each element can be increased by 3 bits (i.e. approximately doubled to 64 states/element). Applying this to the 7-element tag described above, the data capacity becomes $10,000 \times 64^7 = 55$ bits. For the 9-element tag, the data capacity becomes about 74 bits. For an n -element tag, with m states per element, the material-encoded part of the tag data is constructed most
15 easily as an n -digit base- m number. This is added to the angle-encoded part in a similar way to that described above.

For tags where elements overlap each other, little data can be stored by adding bias to the tag – this technique is only generally applicable if the elements are physically
20 separated.

Another particularly favourable arrangement is one in which data is stored by a combination of angle and location.

25 A simple tag consists of a 2D grid, for example, 5x5 locations, 31, as illustrated in Figure 5. A limited number of magnetic elements are arranged on this grid, for example, 7. The elements are disposed at angles relative to each other, in exactly the same way as the coercivity/angle embodiment described above. With 7 elements, about 10,000 different angular arrangements can be stored and each
30 element uniquely identified. The elements can be constructed from a wide range of magnetic wires, ribbons and films. The general requirement is that the element displays a relatively rapid and detectable switching transient in fields changing at more than 100,000 A/m/s. A low-cost embodiment uses 9x9mm squares of soft

magnetic material, for example, Atalante™ thin film material (manufactured by IST of Zulte, Belgium, part number SPR97017A). Any of the materials described above in the coercivity/angle tag embodiment can also be used.

- 5 The first element, 32, generally occupies the same point in the grid, for example, the bottom left. The remaining elements can be positioned at any of the remaining sites. For example, with a 5x5 grid and 7 elements, the remaining 24 sites are filled by the remaining 6 elements, giving 96909120 arrangements (about 26 bits). Thus the total tag data capacity is about 40 bits.

10

Data storage in the location/angle tag described above can be increased in a number of ways. For example, the data content can be increased by using more elements or locations. The penalties of this are that the tag may be larger, or that the reader may require better position resolution to separate out the different location states.

- 15 Using more elements also increases the tag complexity.

Each tag element can also vary in coercivity, dH/dt dependence, switching speed, amplitude response and bias.

- 20 Estimating conservatively:

	Coercivity:	3 bits	(8 coercivities)
	dH/dt	1 bit	(e.g. little/large variation)
	Speed:	1 bit	(e.g. fast/slow switching)
25	Amplitude:	1 bit	(e.g. high/low amplitude)
	Bias:	1 bit	(on/off)

- This shows that around 7 additional bits of data (128 states) can be stored per element. For a 7-element tag, on a 5x5 grid, with 128 states/element, the total data capacity is about 89 bits. For a 9-element tag on a 6x6 grid, the capacity can be
- 30 increased to about 102 bits of data.

It is particularly favourable to manufacture tags with amorphous wire elements where the elements are kept parallel, because this allows the wires to be incorporated into a moving web using standard available equipment. This can also facilitate the use of a simpler reader configuration. Suitable magnetic materials are, for example, bistable glass-coated amorphous metal wires, as described above, or Barkhausen wires.

Figure 6 shows a tag 33, which appears similar to a bar code, constructed from a series of, (in this example) 7 different parallel wires, 34, 35, each 30 mm long, with a choice of, for example, 25 locations at spaced at 2mm intervals, giving a rectangular tag around 30x50mm. The different wire types are used to identify the elements, and data is stored by the location of each element. Using 7 elements, about 26 bits of data can be stored, since one element 34 is assumed to be in a fixed location. Using 9 elements, about 34 bits of data can be stored. Again, data capacity can be increased by selecting the actual elements from a larger pool of available elements, which may differ in amplitude, switching speed or dH/dt variation, or any other measurable magnetic properties.

Combinations of different properties, numbers of allowable states, or numbers of elements are not limited to the embodiments described above. Many factors affect the exact choice of properties to combine in the tag, including the cost of the tag, the size, the required data capacity, the geometry of the reader, the available materials, and the reading environment.

Similarly, the methods used to convert the tag parameters into numeric values are not limited to the methods described in the embodiments above.

Additional discrimination between elements is possible using properties including:

1. Permeability
2. Dependence of switching properties on cross-field bias
3. Barkhausen percentage response as a function of rate of change of field
4. Resonant frequency of magnetostrictive materials

Any of the properties, individually or together with any of the other properties described in this disclosure, can be used to increase the number of states for each element, and hence the total data encoded by the tag.

Claims

1. A magnetic tag for storing data, comprising at least one magnetic element configured such that the data is stored by reference to a combination of two or
5 more characteristics associated with the or each element.
2. A magnetic tag according to claim 1, wherein a first one of the characteristics is used to distinguish the or each element and a second one of the characteristics is used to store data.
10
3. A magnetic tag according to claim 2, wherein a further one or more of the characteristics are used to store additional data.
4. A magnetic tag according to claim 1, 2 or 3, wherein the two or more
15 characteristics include one or more selected from element coercivity, element bias, element orientation, amplitude response of an element, response bandwidth, dependence of element switching field in response to the rate of change of an applied field, element switching speed, element location, maximum cross-field bias, permeability, Barkhausen response and resonant frequency.
20
5. A magnetic tag according to any one of the preceding claims, in which two or more bits of data are stored by the or each element.
6. A magnetic tag according to any one of the preceding claims, comprising a
25 plurality of magnetic elements, each of the magnetic elements being disposed in a different orientation by which it is distinguishable from the other elements and each having a magnetic bias member capable of assuming a plurality of states, wherein data is stored by the state assumed by the magnetic bias member.
- 30 7. A magnetic tag according to claim 6, in which the orientation of each of the elements is selected from a set of possible orientations, whereby to store additional data.

8. A magnetic tag according to claim 6 or 7, in which one or more of the elements is arranged to exhibit a different coercivity, whereby to store additional data.

5 9. A magnetic tag according to claim 6, 7 or 8, in which one or more of the elements is arranged to exhibit a different amplitude response from that of the other elements, whereby to store additional data.

10 10. A magnetic tag according to claim 9, wherein the effective dimensions of one or more of the elements is different from that of other elements to produce a variation in amplitude response.

11. A magnetic tag according to any one of claims 1 to 5, comprising a plurality of intersecting magnetic elements, each of the magnetic elements being disposed in
15 a different orientation by which it is distinguishable from the other elements and each having a coercivity selected from a set of possible coercivities, whereby to store data.

12. A magnetic tag according to claim 11, wherein the relative orientations of
20 the elements are used to identify the elements and to store data, and the coercivities of the elements are used to store further data.

13. A magnetic tag according to claim 11 or 12, wherein the intersecting
25 elements are arranged such that they do not bisect one another.

14. A magnetic tag according to any one of claims 1 to 5, comprising a plurality of magnetic elements, each of the magnetic elements being disposed in a different orientation by which it is distinguishable from the other elements and each being
located at one of a plurality of possible locations whereby to store data.

30 15. A magnetic tag according to any one of claims 1 to 5, comprising a plurality of magnetic elements, each of the magnetic elements being located at one of a

plurality of possible locations and each having a coercivity which is selected from a set of possible coercivities, whereby to store data.

16. A magnetic tag substantially as hereinbefore described, with reference to the
5 accompanying drawings.

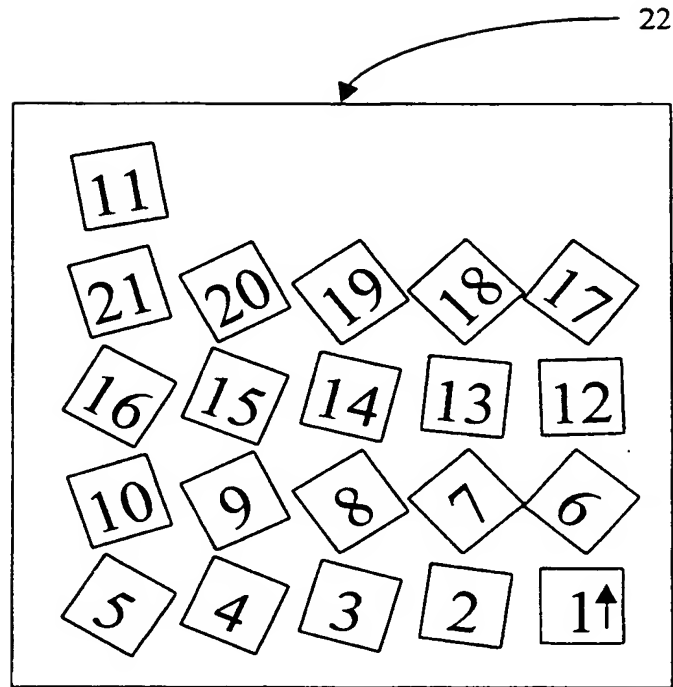


Figure 1

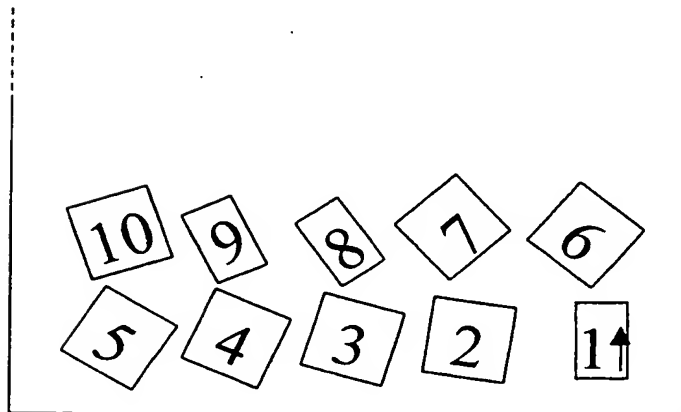


Figure 2

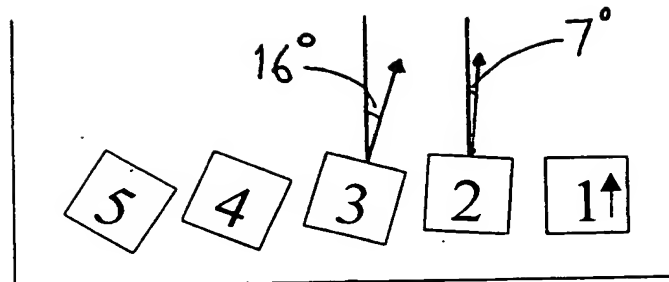


Figure 3

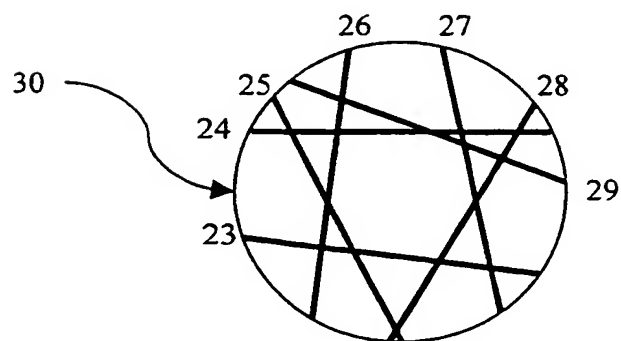


Figure 4

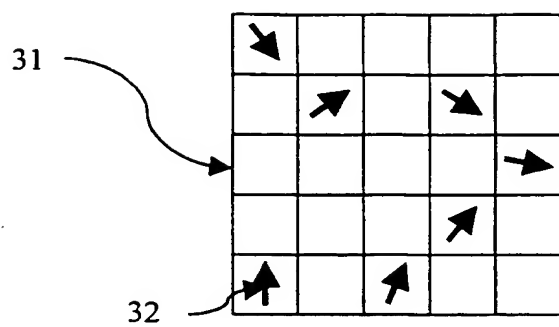


Figure 5

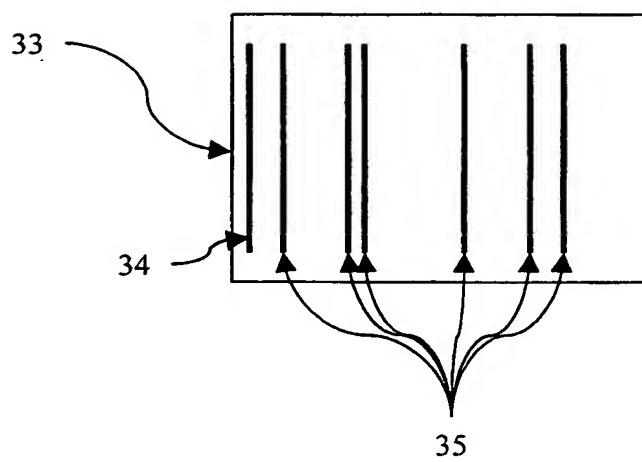


Figure 6

INTERNATIONAL SEARCH REPORT

Inter. Application No
PCT/GB 00/03752

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06K19/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, IBM-TDB, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 195 35 019 A (CARDTEC ENTWICKLUNGS UND VERTR) 27 March 1997 (1997-03-27) column 4, line 29 - line 62; figure 1	1,2,4-6, 11,12, 14,16
X	US 4 940 966 A (PETTIGREW ROBERT M ET AL) 10 July 1990 (1990-07-10) column 3, line 51 - line 68; figures 3,4 claim 2	1,2,4-6, 11,12, 14,16
X	WO 99 28852 A (TECHNICAL GRAPHICS SECURITY PR) 10 June 1999 (1999-06-10) page 14, line 7 -page 16, line 10; figure 4B	1,2,4-6, 11,12, 14,16

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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- *Z* document member of the same patent family

Date of the actual completion of the international search

6 December 2000

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intel. Application No

PCT/GB 00/03752

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